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WRF-HMS, a fully-coupled regional atmospheric-hydrological modeling system for long-term scale applications

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Feedback among the atmosphere, land surface and subsurface is important to understand the non-linear connections within the hydrological cycle. Investigations of climate and land-use changes on the regional water balance require fully-coupled atmospheric-hydrological modeling systems, which describe such feedback mechanisms and allow long-term simulations at climate-relevant scales.

We have developed such a fully-coupled, meso-scale modeling system extending the atmospheric model WRF-ARW with the hydrological model HMS, which includes lateral water fluxes at the land surface and subsurface. Both models are bound to the Noah land surface model (Noah-LSM) and share compatible water and energy flux formulations. In addition, two-way interaction between the saturated and the unsaturated zone is implemented by replacing the free drainage bottom boundary of the Noah-LSM with two approaches, a Fixed-head boundary condition assuming an equilibrium soil moisture distribution or a Darcy-flux at the boundary assuming a quasi-steady-state moisture profile below the LSM. The comparatively small additional computational demand of this coupled model system allows long-term simulations.

A first application of the fully-coupled modeling system was performed for the Poyang Lake basin (160,000 km^2) in Southern China for the years 1979-1986. For the WRF model, a double-nesting approach is applied covering East Asia at 30 km resolution and the Poyang Lake basin at 10 km using ERA Interim data as global forcing. The HMS and fully-coupled simulations are performed on the 10 km grid. The performance of the stand-alone and the fully coupled simulations are presented. Furthermore, the impact of groundwater coupling on soil moisture, evapotranspiration, temperature and precipitation is investigated.